ADVANCED TECHNOLOGY FOR ECONOMICAL DEHUMIDIFICATION TO IMPROVE INDOOR AIR QUALITY

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INTRODUCTION

materials, books, and records deteriorate more rapidly in humidity levels above 60% due to bio-degradation. High humidity increases electrical costs by reducing the temperature required for occupant comfort. Fungal growth in humidities above 70% can have many detrimental health effects, depending on the particular species encountered [5,1]. In fact, high humidity is often an underlying cause of many air quality disorders that result in indoor air quality (IAQ) problems.

Moist environments (above 70% rh) allow the proliferation of microbiological contamination that may cause lethargy, allergic reactions, and disease in people [3, 4, 6]. Airborne pathogens may survive freely in air which has a high relative humidity [5]. Recently, the World Health Organization has identified microbiological contamination in buildings as number five of the top five health threats to properly maintained modern buildings, the most practical way to control microorganisms is to maintain reduced indoor humidity . In fact, the ASHRAE IAQ Standard 62-1989; Section 5.12 states that the relative humidity in all ductwork should be kept below 70%. This condition is easy to meet using the technology described in this paper. Control of indoor fungal growth can prevent a wide variety of serious health impacts for building occupants . The effectiveness of air filters is reduced in high humidity. Finally, the offgassing of chemicals such as formaldehyde, from urea-formaldehyde products, and the perception of odors all increase in high humidity [5] (see Fig. 1.).

Prior to the mid-1970s, humidity was controlled by using a reheat system. In a reheat system, air is overcooled with an air conditioner in order to condense excess water vapor and is then reheated to a temperature suitable for introduction into the occupied space using supplemental heat such as resistance heaters or hot water. In effect, the reheat adds an artificial sensible heat load to the space and achieves humidity control with higher capital and operating costs.

This paper will introduce the dehumidifying Subcool and Desuperheat (SCADR) Heat Pipe System. SCADR increases moisture removal and provides virtually "free" reheat in Direct Expansion (DX) air conditioning systems. When used in place of traditional reheat systems, SCADR dramatically reduces electrical demand and consumption.

COST FACTORS

There are two operating cost factors involved with reheat. First, is the obvious electrical power consumption by the electric heat strips, or fuel consumption for a hot water system. Less obvious is the additional power consumption required by the air conditioner to remove the reheat heat load. Besides increased annual operating costs, capital costs are higher. Overcooling the moist air and handling the supplemental heat load requires an air conditioner which is 20 to 50 percent larger than a unit that does not overcool and actively reheat.

PROBLEMS WITH DX SYSTEMS

There is nothing inherently wrong with DX Systems. However, problems will arise when the system is required to meet performance criteria, of which, it is not capable. We all know that oversizing usually results in high humidity levels. This is because the system satisfies the thermostat quickly and does not operate long enough to remove sufficient moisture. Adding a humidistat will do little to improve comfort conditions. A continuous fan operation, with ventilation air, further compounds the problem. Proper sizing will usually provide sufficient humidity control, but only at peak load conditions (typically 95 degrees F outdoors, sunny and all the lights on). Peak load conditions occur a small percentage of the time.

The cooling capacity of DX equipment is rated at 95 degrees F outside air on the condensing coil. When the outside air is cooler, the systems capacity increases while the cooling load decreases. This results in an oversized system and a need for reheat. An oversized system can also result from certain energy conservation measures such as lighting retrofits and adding thermal insulation both of which reduce cooling loads.

HEAT PIPE OPERATING PRINCIPLE

Heat Pipes are highly efficient, passive devices which transfer heat. In its simplest form, a Heat Pipe is a sealed tube which has been evacuated, charged with a precise amount of refrigerant, and sealed (see fig. 2.). The Heat Pipe is then positioned so that one end is in a heat source and the other end is in a heat sink. The refrigerant on the warm side absorbs heat, boils, and flows to the cold side. Here it condenses, releases heat and returns to the warm side by gravity to complete the process. This boiling and condensing continues as long as a temperature differential exists between the two ends of the Heat Pipe. No pumps, blowers or power input is required for the Heat Pipe's operation.

SCADR OPERATING PRINCIPLE

SCADR uses the heat contained in the DX system's liquid line (subcooling) and hot gas line (desuperheating) to provide controllable reheat and increase moisture removal (see fig. 3.) A Heat Pipe is used to transfer heat from the warm liquid line of the refrigeration system (subcooling) to the cold air leaving the evaporator to provide free reheat. The subcooling of the liquid refrigerant increases the cooling capacity at the evaporator resulting in an increase in moisture removal. In many SCADR systems, the liquid refrigerant is subcooled directly by passing it through a coil in the supply air. After subcooling, the liquid refrigerant flows into the evaporator. The subcooling/reheating step can be continuous or controlled. In addition, a Heat Pipe is used to transfer heat from the hot gas discharge line of the compressor (desuperheating) to the cold air leaving the evaporator to provide additional reheat in a controlled manner to provide humidity control at low cooling load conditions.

SCADR is applicable to both recirculation and 100 percent outside air units.

EXAMPLE PERFORMANCE

To demonstrate the performance enhancement of SCADR, we will look at a ten ton, EER 9.0, DX system operating at 3,750 CFM using ASHRAE design conditions of 80 degrees dry bulb and 67 degrees wet bulb. To demonstrate the energy savings, economics, and positive environmental impact, we will compare the SCADR to an electric reheat system.

Without SCADR, the system performs ten tons of cooling at the evaporator and removes 29.2 pounds per hour of moisture. With SCADR, the system performs 11.8 tons of cooling at the evaporator and removes 41.2 pounds per hour of moisture due to the subcooling process. In addition, the subcooling provides the equivalent of 6.3 KW of free reheat. Finally, another 7.0 KW of controllable reheat is available from the Desuperheat Reheat Heat Pipe Loop to provide humidity control at low cooling load conditions (see fig. 4).

Total electrical peak demand is reduced by 15.8 KW. If this system is operated 12 hours per day and 35 weeks per year, the system would save 46,530 KWH and $3,462.00 per year (including the SCADR coil air pressure drop.). Considering only the energy dollar savings, the simple payback is 1.2 years with a return on investment of 81%. When the capital cost differential of an 11.8 ton unit with reheat controls vs ten tons with SCADR is considered, the payback approaches six months (see table 1.).

The appendices include a psychrometric chart showing the performance enhancement of the SCADR Syetem (see fig. 5.).

POSITIVE ENVIRONMENTAL IMPACT

Conserving 46,530 KWH per year prevents the burning of 23.3 tons of coal at an electric power plant every year. This reduces the emission of 37.2 tons of carbon dioxide annually. In addition, sulfur dioxide is reduced by 931 pounds and nitrogen oxides by 279 pounds (see table 1.).

CONCLUSIONS

This paper clearly shows that the SCADR System can economically control humidity and improve Indoor Air Quality. Furthermore, dry, rather than saturated, air is introduced into the supply ductwork. Finally, SCADR can easily maintain the relative humidity in the conditioned space between 40 and 50%, in which range microorganism growth is reduced.

REFERENCES

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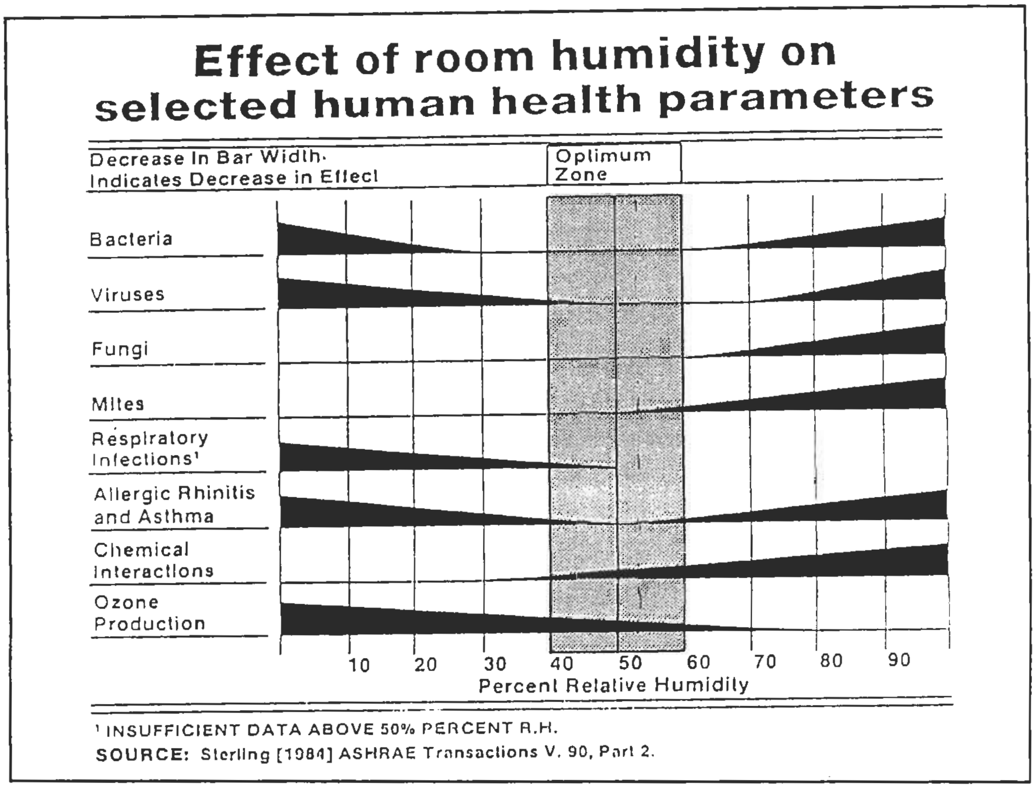


Figure 1

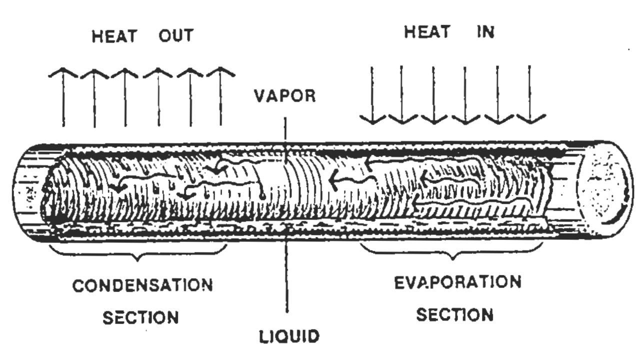


Figure 2

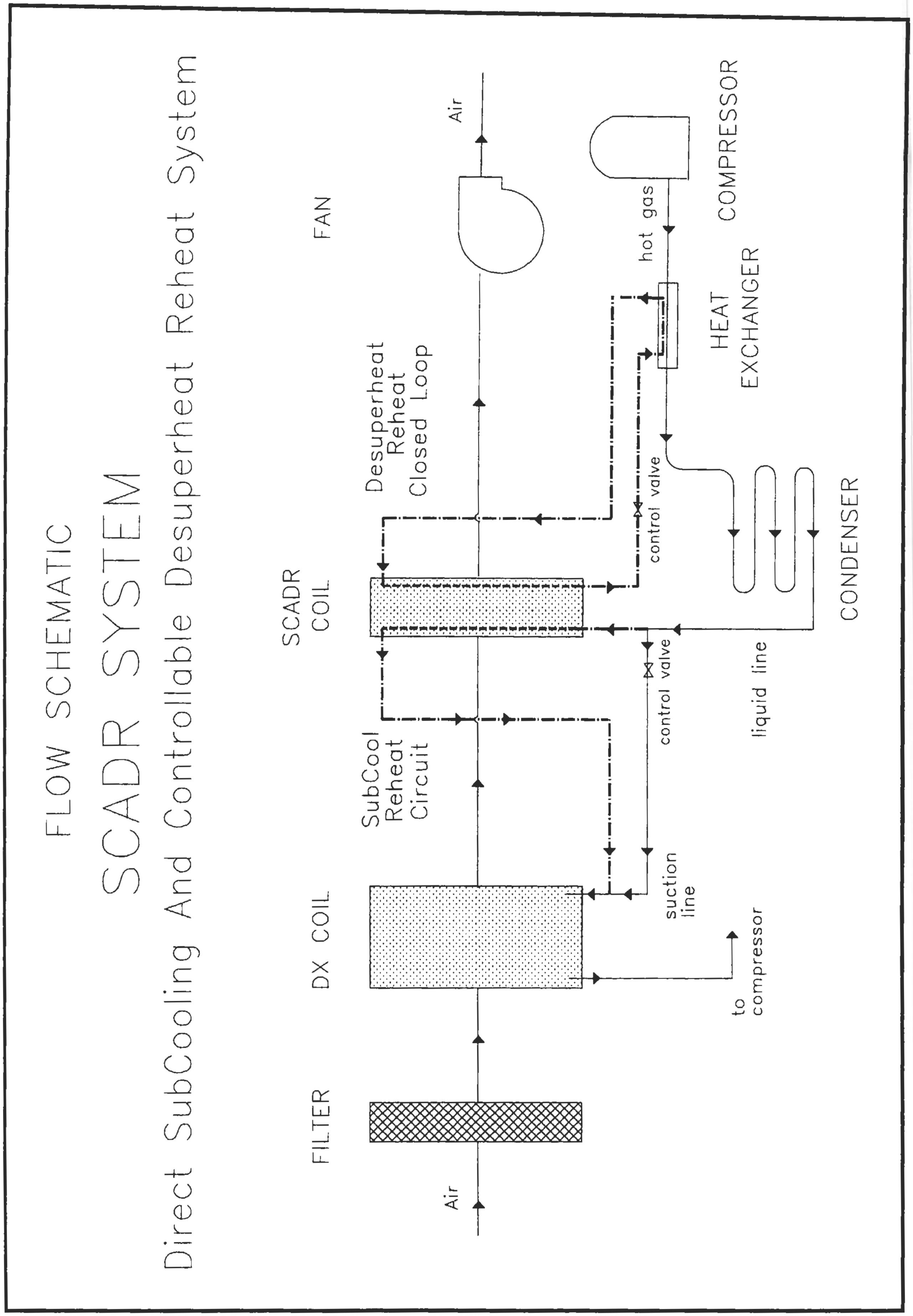
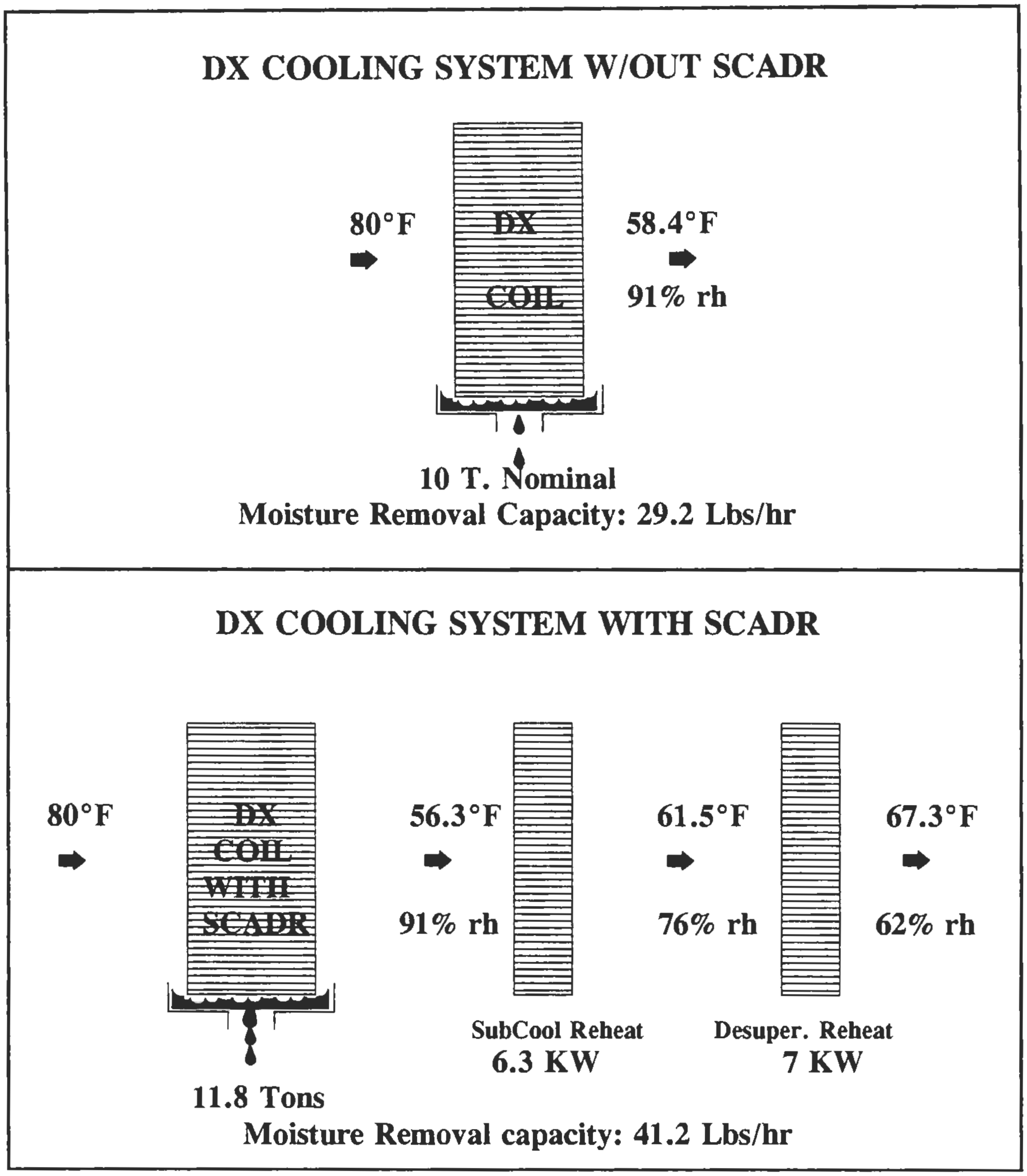
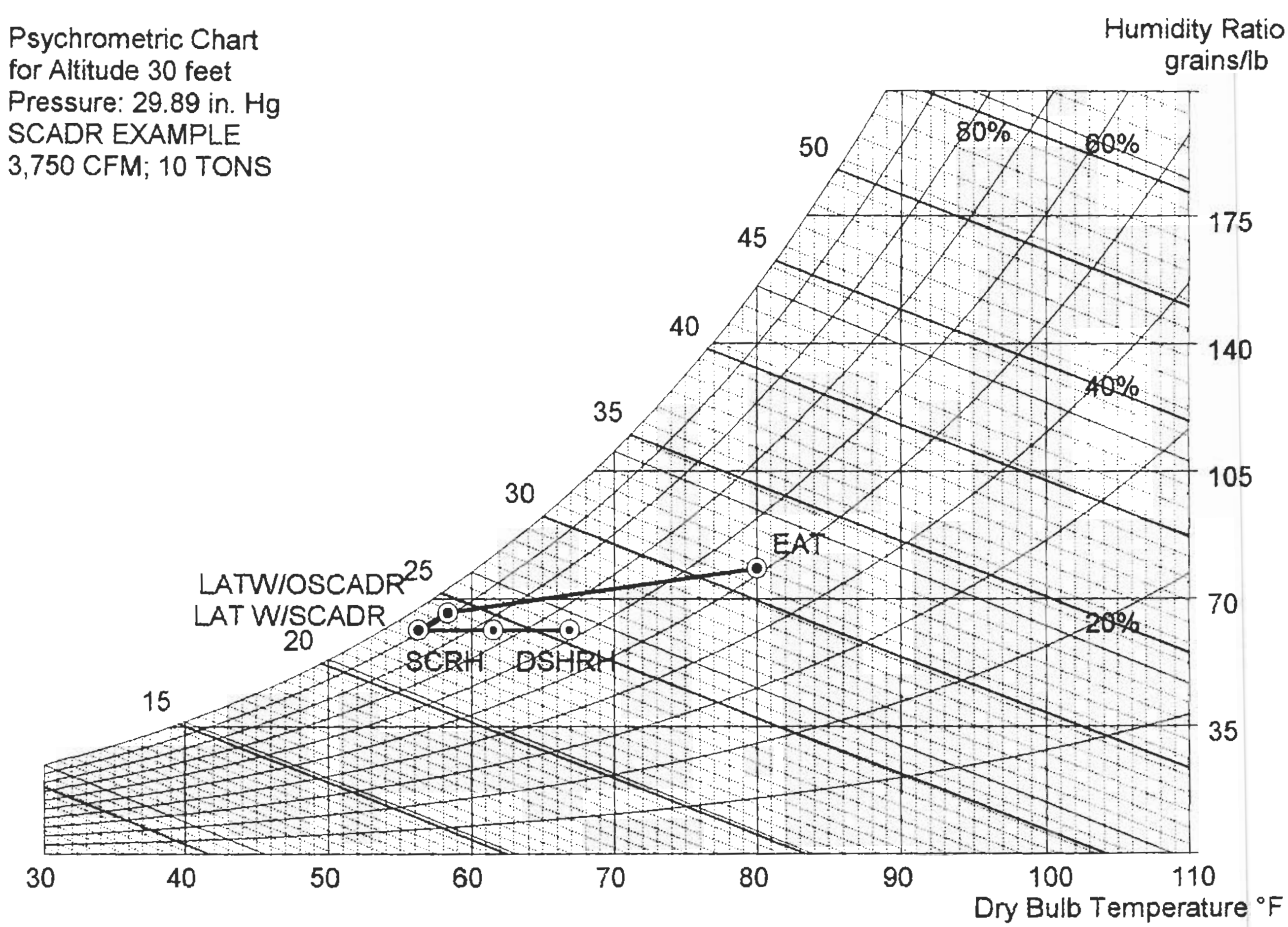

FLOW SCHEMATIC
SCADR SYSTEM
Direct SubCooling And Controllable Desuperheat Reheat System
FILTER
DX COIL
SCADR COIL
FAN
Air
Air
SubCool Reheat Circuit
Desuperheat Reheat Closed Loop
suction line
to compressor
control valve
control valve
liquid line
hot gas
HEAT EXCHANGER
COMPRESSOR
CONDENSER

Figure 4
SubCool And Desuperheat Reheat: Recirculation Example



1. The SCADR system transfers heat out of the liquid line to increase the evaporator capacity by 1.8 tons.
2. The heat removed from the liquid line is transferred by a heat pipe into the supply air to provide 6.3 KW of passive reheat.
3. Moisture removal is increased 41% using the same cooling energy.
4. Dry air rather than saturated air is introduced into the supply ductwork (ASHRAE Std. 62-1989; Section 5.12; relative humidity of air in ductwork).



State Point Data

State Point	Dry Bulb °Fdb	Wet Bulb °Fwb	Dew Point °Fdp	Relative Humidity %RH	Humidity Ratio grains/lb	Specific Volume ft³/lb	Enthalpy Btu/lb
EAT	80.00	67.00	60.29	51.12	78.3	13.87	31.46
LATW/OSCADR	58.40	56.80	55.72	90.92	66.3	13.27	24.31
LAT W/SCADR	56.30	54.80	53.72	91.18	61.6	13.21	23.06
SCRH	61.58	56.89	53.72	75.48	61.6	13.34	24.35
DSHRH	66.91	58.92	53.72	62.64	61.6	13.48	25.65

Figure 5

Table 1

AMERICAN HEAT PIPES, INC.
SCADR ENERGY ANALYSIS
COMPARED TO ELECTRIC REHEAT

PROJECT:	SCADR EXAMPLE	3,750 CFM
LOCATION:	JACKSONVILLE, FL	3,800 SUBCOOL OP. HRS./YR.
UNIT:	AHU-1	1,900 DESUPER. OP. HRS./YR.

SCADR SYSTEM

18 % SUBCOOL	20 % DESUPERHEAT REHEAT
21,600 SUBCOOL BTUH	24,000 DESUPERHEAT REHEAT BTUH
5.3 SUBCOOL REHEAT DELTA T	5.9 DESUPERHEAT REHEAT DELTA T
	0.17 HEAT PIPE PRESSURE DROP

UTILITY COSTS

NA PER KW DEMAND COST $0.075 PER KWH

DEMAND REDUCTION

6.3 KW SUBCOOL REHEAT	7.0 KW DESUPER. REHEAT
2.4 KW COOLING ENERGY	

15.8 KW TOTAL PEAK DEMAND REDUCTION

ANNUAL KWH SAVINGS

24,049 KWH SUBCOOL REHEAT	13,361 KWH DESUPER. REHEAT
9,120 KWH COOLING	46,530 TOTAL KWH

ANNUAL DOLLAR SAVINGS

$3,490 ANNUAL KWH DOLLAR SAVINGS $28 ADDED FAN DOLLARS

$3,462 TOTAL ANNUAL OPERATING COST SAVINGS WITH FAN DOLLARS ADDED

RETURN ON INVESTMENT AND PAYBACK

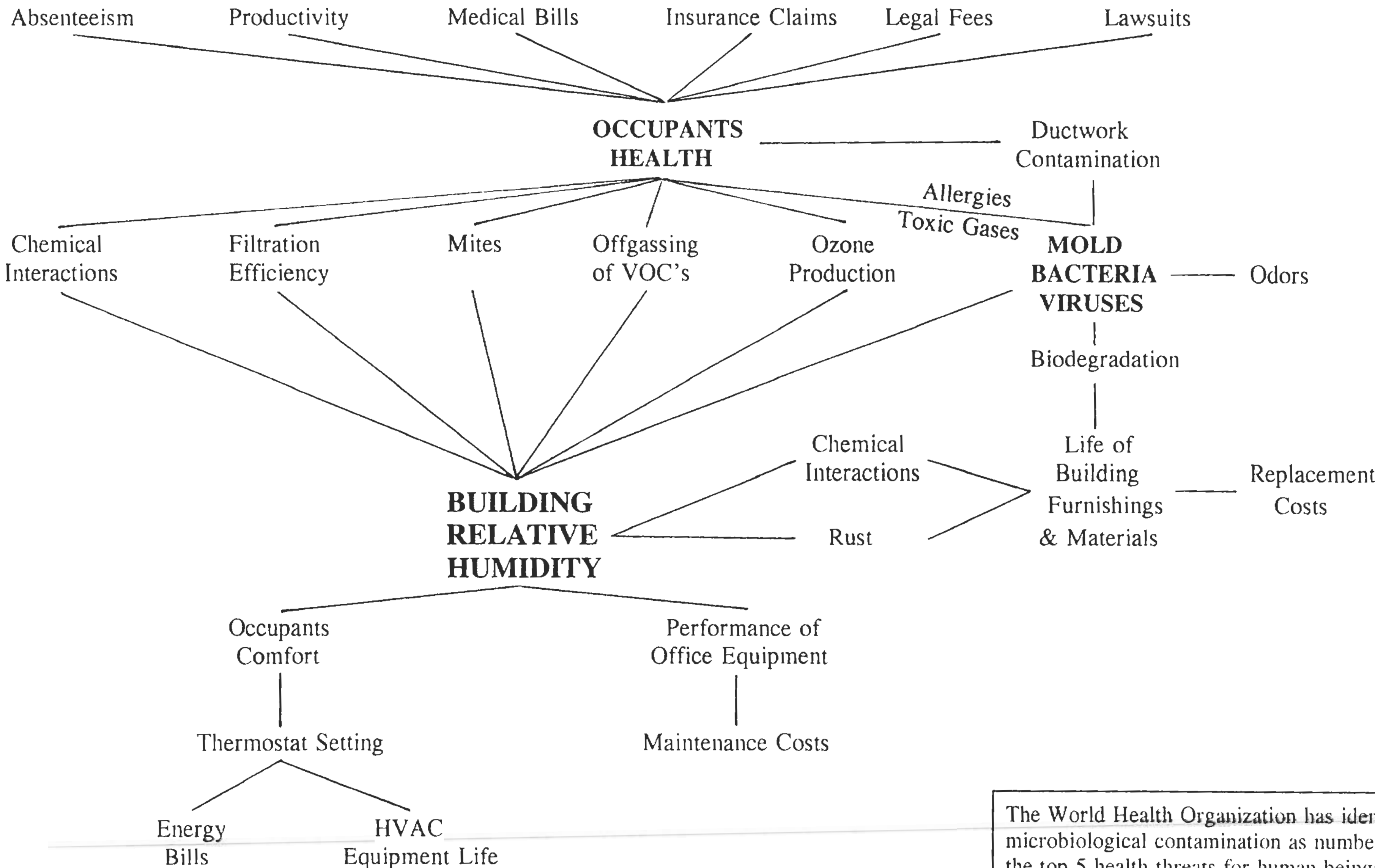
$4,020 INSTALLED COST OF SCADR 86.1 % RETURN ON INVESTMENT

1.2 YEAR PAYBACK 0.72 YRS. VS 12 TONS INSTALLED)

POSITIVE ENVIRONMENTAL IMPACT

23.3 TONS ANNUAL SAVINGS OF COAL
37.2 TONS ANNUAL REDUCTION OF CARBON DIOXIDE
931 POUNDS ANNUAL REDUCTION OF SULFUR DIOXIDE
279 POUNDS ANNUAL REDUCTION OF NITROGEN OXIDES

The Effects of Relative Humidity When Above 60% In Buildings



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